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SHEEP RESEARCH
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¹North Central Region, Agricultural Research Service, U. S. Department of Agriculture

U.S. MEAT ANIMAL RESEARCH CENTER¹

Clay Center, Nebraska

SHEEP RESEARCH PROGRAM

INTRODUCTION

The U.S. Meat Animal Research Center Sheep Research Program places highest priority to the development of intensive and moderately intensive sheep production system technology capable of having an immediate and major impact on the efficiency of meat production from sheep. Research emphasis is placed on the generation of technology which can be practically implemented by commercial sheep producers within a relatively short time frame. Meeting these technology requirements will enable sheep to become more competitive for resource use.

The multidisciplined sheep research program at the U.S. Meat Animal Research Center is designed to complement existing domestic and international research programs in the development of sheep production technology. Problem areas considered to have the highest immediate pay-off potential for increased efficiency of lamb production with desired consumer acceptability are identified in this document.

Specific research efforts will not be oriented toward wool production problems because of research efforts relating to wool in State Agricultural Experiment Station and other ARS programs. However, quantity and quality of wool production will be monitored in all major projects and where appropriate, collaborative efforts on wool production problems may be developed with a cooperator who could provide primary leadership for the joint efforts.

The sheep research program at the U.S. Meat Animal Research Center is organized on a multidiscipline basis with the focus on the solution of specific problems that represent the greatest technological constraints to improving production efficiency and product desirability. For convenience, the research program is reviewed on a discipline basis in this document with problem areas listed under the disciplinary unit that is taking the lead on research programs in each specific problem area.

¹ North Central Region, Agricultural Research Service, U.S. Department of Agriculture.

I. GENETICS AND BREEDING

A. General Objective. Identify and develop for industry use: superior germ plasm resources, optimum methods of utilizing germ plasm resources and among/within breed selection procedures necessary to optimize genetic improvement in production efficiency and product desirability.

B. Specific Programs.

1. Research Area:

Germ Plasm Evaluation

a. Objective:

Determine adaptability of domestic and newly-introduced breeds as maternal and paternal stocks for efficient market lamb production systems under intensive and semi-intensive management.

b. Research Accomplishments or Progress:

- (1) Reproductive, growth and carcass performance as pure-breeds and in crosses has been evaluated (1969-1974) for established Suffolk (S), Hampshire (H), Polled Dorset (D), Rambouillet (R), Targhee and Corriedale breeds of dam and for imported Finnsheep sires under spring lambing, early (6 or 10 week) weaning and feedlot rearing management. Purebred comparison of domestic breeds involving about 2,000 ewes over 4 years indicated that differences among seven domestic (U.S.) breeds were minor in fertility, moderate in lambing rate ($\pm 5\%$) but large in lamb growth ($\pm 15\%$) and appreciable in carcass traits. Crossbred evaluation included viability, growth and carcass information from 1,930 Finn (F_x) and 530 Rambouillet (R_x) sired crossbred and 1,170 purebred (P) lambs from ewes of seven domestic breeds and ewe performance for about 800 F_x , R_x and P ewes bred to lamb at 1 to 4 years of age. From these ewes, growth and carcass traits have been evaluated for nearly 2,000 ewe and wether lambs by S, H and Oxford (O) sires. In crossbred performance, F_x surpassed R_x and other domestic crosses in viability and equaled all but Suffolk crosses in 10-week weight. Dam-breed effects were negligible for viability but large for 10-week weight of F_x . Heterosis for livability and 10-week weight was less in domestic crosses (13 and 3%) than in F_x from S, H and D dams (~50 and 10%), but negligible in F_x from R and Coarse Wool dams. F_x equaled R_x in growth to 22 weeks but were slightly lighter, fatter and lower

in lean cut yield at later slaughter ages. The 22-week weights of F_X lambs ranged between 41 for D and 50 kg for S dams. F_X lambs from S, H or D dams excelled in dressing % and carcass conformation; these plus 1/2 R lambs had the least fat and highest % lean cut yield.

F_X ewe lambs reached puberty 3 weeks before R_X and were higher in conception rate (85/66%) at 6 to 8 months but not in later fertility. F_X exceeded R_X ewes in lambs born per 100 ewes lambing at 1 year (154/106), 2 years (195/137) and 3 years (193/177) of age. Lambs from F_X , R_X and P ewes mated to S, H and O rams differed some in 26-week weights (42, 45 and 44 kg) but not in lean cut yields (10 kg). Lambs from 1/2 S, H and D ewes exceeded others only in leg conformation and dressing %. Under intensive spring lambing management, average expected relative lean lamb meat production from 1- to 3-year-old F_X , R_X and P ewes is about 136, 100 and 86, respectively.

- (2) In 1973 and 1974, about 400 Border Leicester- and Finn-sired lambs from Hampshire, whitefaced and 1/2-Finn ewes were produced to evaluate Border Leicester relative to Finn as a maternal breed. Viability and growth data were obtained for lambs of both sexes with cooler carcass data on ram lambs; ewe lambs were bred to Suffolk sires to evaluate ewe performance at 1 year of age.

c. Current Status:

- (1) The last lamb crop from F_X , R_X and P ewes, (1.b. (1) above), was born in 1974. In collaboration with Wilson and Co., retail cut yields, composition and meat quality information have been obtained on over 800 of the 1974 spring ewe and wether lambs to supplement data from uncut carcasses in previous years.
- (2) The final set of about 250 F_1 lambs from Border Leicester (B_X) and Finn sires and the first Suffolk-sired lambs from 1-year-old B_X and F_X ewes were produced in 1974. Viability and growth data on both sexes and cooler carcass data on ram lambs were obtained. B_X and F_X ewes were bred in fall, 1974, to lamb at 1 and 2 years of age in 1975.

d. Research Plans:

The evaluation of the first cycle of breeds terminated with collection of carcass data on the 1974 lambs from Rambouillet-cross, Finn-cross and purebred ewes by Suffolk, Hampshire and Oxford sires. No further production of Border Leicester vs. Finn F_1 crosses is planned. The 180 B_X and F_X ewes born in

1973 and 1974 will be bred to Suffolk sires to evaluate ewe performance through 3 or 4 years of age. If and when import regulations permit, other promising breeds will be selected for evaluation, based upon purebred and crossbreeding performance data from countries of origin.

2. Research Area:

Germ Plasm Utilization

a. Objectives:

- (1) Determine the proportion of initial heterosis in individual and maternal performance retained in inter se mating from a crossbred foundation for use in predicting performance levels from alternative crossbreeding systems and multibreed synthetics.
- (2) Measure response to selection for superior maternal performance in multibreed synthetics, without cumulative inbreeding, (a) to evaluate net effects of expected greater genetic variability, selection intensity and heterosis retention in synthetics and (b) to produce superior maternal lines for industry use under intensive production systems.

b. Research Accomplishments or Progress:

- (1) Important heterosis levels have been demonstrated in viability, early growth and age at puberty from crosses of Finnsheep and of domestic breeds. A 6-year project to determine degree of individual and maternal heterosis retention from Suffolk x Hampshire crosses began in 1973. The design involves intra-year comparison of parental purebreds, F_1 , F_2 and F_3 generations and backcrosses of F_1 to both parent breeds. About 390 purebred, 460 reciprocal F_1 cross and 80 F_2 lambs were produced in 1973, 1974 and 1975. Viability, growth, postweaning feed consumption, cooler carcass characteristics (ram) and ewe performance are being measured.
- (2) Sufficient crossbreeding evaluation of Finnsheep and of domestic breeds has been completed to guide selection of constituent breeds for two maternal multibreed synthetic combinations. One is $1/2$ Finn, $1/4$ Rambouillet, $1/4$ Dorset, chosen especially for potential adaptation to accelerated lambing rate, lamb viability and carcass desirability. The other is $1/2$ Finn, $1/4$ Suffolk, $1/4$ Targhee, chosen because of superiority in potential size and carcass merit of market lambs plus early maturity and lambing rate of ewes under annual lambing

or induced year around fertility.

c. Current Status:

- (1) Numbers of F_1 Suffolk x Hampshire matings were increased in the heterosis retention project to permit adequate numbers of backcross, F_2 and F_3 matings in 1975 and 1976. Parental and F_1 matings will be made in single sire pens to permit genetic analyses of the data.
- (2) The Finn x (Dorset-Rambouillet) foundation matings were initiated in fall, 1974, with reciprocal crosses of available Finn-Dorset with Finn-Rambouillet breeders. Straightbred matings of elite Finn, Dorset and Rambouillet were also made. The $1/2$ Finn, $1/4$ Suffolk, $1/4$ Targhee synthetic was initiated in fall, 1975, with reciprocal matings of Finn-Suffolk with Finn-Targhee breeders. Straightbred matings of Targhee were also made. Straightbred Finn and Suffolk flocks were already available and will be used in evaluation of this second multibreed maternal synthetic.

d. Research Plans:

- (1) The Suffolk-Hampshire heterosis retention project involves intra-year comparison under intensive spring lambing management of parental, reciprocal F_1 cross, F_2 and F_3 inter se and reciprocal backcross matings of ewe lambs, 1-, 2- and 3-year-old ewes for spring lambing in 1976, 1977 and 1978. Numbers of ewes mated per year will be about 700, 800 and 800, respectively, for 1975, 1976 and 1977. Relatively large numbers of single sire matings are being used to permit genetic analysis and to avoid inbreeding and genetic drift error. Performance data recorded includes fertility, sexual maturity, lambing rate, viability, growth, feed consumption from early weaning (replicate pens within type of mating) and carcass conformation and composition (of surplus ram lambs only).
- (2) The multibreed maternal synthetic development project will involve comparison of the Finn x (Dorset-Rambouillet) and Finn x (Suffolk-Targhee) synthetic populations and parental populations of all. Elite populations of Finn, Dorset and Rambouillet will be subjected to the same selection for maternal performance as are the two synthetic populations. Unselected Finn, Rambouillet, Targhee and Suffolk populations will also be utilized. About 2,000 breeding ewes will be involved in this project for an anticipated 5 years (1975-1980).

3. Research Area:

Maternal Breed Selection Criteria

a. Objectives:

- (1) Develop and evaluate selection criteria and procedures capable of making rapid genetic improvement for early sexual maturity, fertility, lambing rate, length of breeding season and lamb performance of maternal breeds.
- (2) Utilize appropriate selection criteria in the development of superior germ plasm for industry use. Small, elite flocks (200 to 300 ewes per breed) of Finnsheep, Dorset and Rambouillet, and two maternal synthetic breeds (400 ewes per breed) are to be developed as maternal germ plasm for industry use and for use in specialized research efforts involving maternal traits.

b. Research Accomplishments or Progress:

- (1) Data on over 1,900 ewe-years of production indicate that important genetic (breed and cross) differences exist in earliness of sexual maturity, lambing rate per ewe exposed and lambing rate per ewe lambing. Additional data on 1,488 ewes indicates that breeds respond differently to exogenous hormone therapy during seasonal anestrous, suggesting the existence of genetic variability for response to hormone initiated out-of-season breeding.

c. Current Status:

Fall, 1975, pedigree matings involving Dorset, Rambouillet and 7/8 and purebred Finnsheep were made. Matings were also made in 1974 and 1975 to initiate development of one synthetic population of 1/2 Finn, 1/4 Dorset and 1/4 Rambouillet breeding -- a highly prolific combination potentially adapted to out-of-season breeding in accelerated lambing programs. Initiated in fall, 1975, was a second synthetic of 1/2 Finn, 1/4 Targhee and 1/4 Suffolk -- a highly prolific combination adapted for use in heavyweight lamb production with use of hormone therapy necessary to induce out-of-season breeding for accelerated lambing programs.

d. Research Plans:

Data on pedigree matings of purebred elite populations and F_1 and F_2 combinations in synthetic breed populations will be utilized to evaluate selection criteria for earliness of

sexual maturity, fertility, ovulation rate, lambing rate, length of breeding season and lamb performance. Effectiveness of selection procedures and the role of new breed synthesis in utilizing germ plasm resources will be evaluated from the responses obtained in the synthetic and the parental breed populations.

4. Research Area:

Paternal Breed Selection Criteria

a. Objectives:

- (1) Develop selection criteria and procedures capable of accelerating the rate of genetic improvement for rapid and efficient growth with desirable lean-to-fat ratio at heavy weights in paternal breeds.
- (2) Utilize appropriate selection criteria for the development of a flock (500 ewes) of rapid gaining, late maturing Suffolks with optimum lean-to-fat ratio at heavy slaughter weights.

b. Research Accomplishments or Progress:

Genetic parameters for preweaning and postweaning growth and carcass traits have been estimated from data on 2,227 pedigreed Suffolk, Hampshire, Dorset, Rambouillet, Targhee, Corriedale and Coarse Wool lambs weaned at 10 weeks of age, 894 ram lambs fed and 584 slaughtered at 24 to 26 weeks of age over three years. Unadjusted gain from 14 to 22 weeks of age and adjusted (for ewe age and type of birth) 22-week weight were identified as highly heritable traits which would be very useful selection criteria for improving efficiency and maintaining carcass desirability of ram lambs killed at moderately heavy weights (110 to 120 lbs.).

c. Current Status and Research Plans:

Matings have been initiated for a population of purebred Suffolks to be selected for paternal characteristics. An unselected population of Suffolks currently involved in the study of epistatic recombination loss will serve as an experimental control to the selected population in the early stages of development. Efforts will continue to develop and evaluate those selection criteria seemingly most appropriate to the development of a "giant" paternal breed with rapid growth, large size and optimum lean-to-fat ratios at heavy slaughter weights. This will not be regarded as a selection experiment, per se, but rather a population for the development of selection criteria and procedures for maximum growth of edible portion to heavy market weights.

II. NUTRITION

A. General Objective. Develop efficient feeding programs for optimizing performance levels, minimizing production costs, enhancing product merit and maximizing net economic returns from high performance breeding flocks and market lambs growing to heavy slaughter weights. Efforts will be oriented toward maximum utilization of high roughage diets and the use of NPN (non-protein nitrogen) as a major source of supplemental nitrogen for both growing-finishing and reproducing animals.

B. Specific Programs.

1. Research Area:

Early Weaning

a. Objectives:

(1) Develop programs to provide for management and nutritive requirements of lambs weaned as early as one day of age.

b. Research Accomplishments or Progress:

One hundred sixty-eight day-old lambs from eight breeds born in the spring of 1970, and 87 Finnsheep-sired lambs born in the fall of 1970, were used in two trials to determine the optimum nutrient levels in lamb milk replacer diets. In the first trial, increasing the fat level in the dry milk replacer from 20% to 30% and reducing the lactose level from 42% to 32% improved rate and efficiency of lamb gain by approximately 75% and reduced lamb death losses by one-half. Reducing the percent lactose in the 30% fat milk replacer in the second trial to 27% lactose resulted in further marked improvements in rate and efficiency of lamb growth and reduction in lamb death losses.

c. Current Status and Research Plans:

Day-old weaning is currently utilized only with orphan, triplet or weak twin lambs. Weaning at 40 to 45 days of age is a routine management procedure. Early weaning programs will receive renewed emphasis as more prolific germ plasm and highly intensive management systems are utilized. Attention will be given to both pre- and postnatal nutritional regimes. Lambing data from the previous four or five years will be analyzed for the causes of early neonatal lamb mortality.

2. Research Area:

Nutrition of Highly Productive Ewes

a. Objectives:

- (1) Develop feeding programs for early expression and continuation of maximum reproductive performance in ewes with high reproductive potential.
- (2) Determine the effect of dietary protein and energy on reproductive performance of 1/2- and 3/4-Finnsheep ewes.
- (3) Determine the optimum level of dietary crude protein and digestible energy during the last six weeks of gestation for maximum rate of reproduction, lamb livability and performance up to weaning.

b. Research Accomplishments or Progress:

- (1) Approximately 400, 2-year-old and 81 yearling F₁ Finn ewes were limit-fed 9 rations in a 3x3 factorial design of protein (P) and energy (E) beginning approximately on day 105 of gestation with three ewes from each treatment in each age group maintained in metabolism crates during the experimental period. From regression equations for absorbed nitrogen (N) vs. retained N, the quantity of apparent absorbed nitrogen (AAN) required to maintain N balance for ewes housed indoors was estimated to be 274 and 371 mg/kg B.W.^{0.75}/day in 2-year-old ewes at 114 and 134 days of pregnancy and 169 mg/kg B.W.^{0.75}/day in yearlings at 134 days of pregnancy. Regression analysis of N intake vs. fecal N at these periods indicated that endogenous fecal N loss was 66 and 69 mg/kg B.W.^{0.75}/day in 2-year-old ewes and 37 mg/kg B.W.^{0.75}/day in yearlings, and true protein digestibility was 73, 72 and 67%, respectively. Increasing dietary N intake increased AAN (P<.05), while increasing dietary E intake decreased AAN and urinary N (P<.01). Weight gains (g/hd/day) for 2-year-old ewes were 199, 368, 240, 388, 447, 506, 430, 495 and 550 for LP-LE, LP-ME, LP-HE, MP-LE, MP-ME, MP-HE, HP-LE, HP-ME and HP-HE where L, M and H represent low, medium and high. Level of P intake did not significantly affect orotic acid excretion; however, urinary orotic acid excretion decreased as E intake increased (P<.05) at 109-113 days of gestation in 2-year-old ewes and at 120-124 days of gestation in yearling ewes. Similar trends were observed at 124 days but not at 135 days of pregnancy in 2-year-old ewes. These data suggest that protein requirements increase with stage of gestation and that the 2-year-old ewe requires more protein than the yearling ewe.

- (2) The effect of three levels of dietary energy on maternal glucose entry rate, fetal liver and heart glycogen DNA, RNA and protein concentrations and early neonatal survival was studied in 230 two- and three-year-old Finnish Landrace crossbreed (1/2) ewes. Increasing the level of dietary energy intake during late gestation increased average lamb birth weight, ewe plasma glucose and insulin and decreased plasma free fatty acids. Rates of glucose appearance were lowest in ewes fed the lowest energy level compared to ewes fed the two higher energy levels. Plasma glucose and glucose appearance rates tended to increase during an intravenous infusion of propionate (1 mmole/min) in ewes fed the lowest energy level but not in ewes fed the two higher energy levels. Ewe plasma glucose increased 3- to 4-fold within 30 minutes of parturition compared to prelambling concentrations. Lambs born to ewes fed the lowest energy level had a lower concentration of liver DNA but level of maternal dietary energy did not significantly affect liver or heart tissue concentrations of RNA, protein or glycogen or heart DNA concentrations. Level of maternal dietary energy did not significantly alter early neonatal survival of lambs. However, lambs born as triplets had lighter birth weights and a decreased survival at weaning compared to lambs born as singles.
- (3) The effects of (1) a pulse injection of insulin (4.4 IU) into nonpregnant ewes (2) a continuous infusion of insulin (0.14 IU/min) in pregnant and nonpregnant ewes and (3) a continuous infusion of glucose (1.2 mg/kg body weight/min) in pregnant ewes on in vivo gluconeogenesis and glucose uptake by the gravid uterus were studied using a primed continuous infusion of U-¹⁴C-glucose. When glucose was infused at a rate of 57% of the endogenous rate of glucose appearance, endogenous glucose production declined to about 67% of the control rate. The response of pregnant and nonpregnant ewes to a continuous insulin infusion was similar. After 60 minutes of insulin infusion, plasma glucose had declined to 39 to 49% of the control level and rates of glucose appearance and disappearance decreased by 11 to 27%. Uterine glucose uptake in pregnant ewes decreased from a control rate of 21.0 ± 5.9 to 5.3 ± 3.6 mg/kg fetus/min following insulin infusion. In pregnant ewes with 1, 2 or 3 fetuses at 109 ± 1.5 days of gestation, glucose uptake by the uterus and its contents accounted for 42.6% of total glucose turnover. Although glucose uptake by the gravid uterus tended to increase with increasing number of fetuses, it was very similar in ewes with 1, 2 or 3 fetuses if expressed as milligram glucose uptake per kilogram fetus per minute ($\bar{x} = 18.0 \pm 2.1$).

c. Current Status:

Research is continuing in order to define the needs for nutrients by the conceptus at differing stages of gestation and in ewes gestating different numbers of fetuses. Data from previous experiments are being prepared for publication.

d. Research Plans:

Utilization of highly prolific germ plasm represents the key element in making sheep more competitive for resource use; thus, continued major efforts are planned in nutrition-reproduction research with these biological types of ewes. Specific objectives for future research include determining the extent that the fetal lamb can fulfill its needs for glucose by gluconeogenesis. Feeding programs for ewes lambing first as yearlings and gestating and nursing two or more lambs will be the focus of these efforts. Specific attention will be given to reducing early postnatal mortality through the nutritive environment of both the ewe and the lamb.

3. Research Area:

Feeding Programs for Production of Heavy Slaughter Lambs

a. Objectives:

- (1) Develop feeding programs for economically growing lambs to heavy market weights with optimum lean-to-fat ratios and desirable carcass palatability characteristics. Efforts will be oriented toward maximum utilization of high roughage diets and NPN as a major source of supplemental nitrogen.
- (2) Develop feeding programs for maximum expression of genetic growth potential to very heavy weights in paternal germ plasm.

b. Research Accomplishments or Progress:

- (1) A study involving 324 intact males from eight breeds of sheep indicated that breeds may differ in their ability to respond to increases in ration concentrate level. Hampshire and Suffolk lambs exhibited increased growth with ration concentrate levels of up to 90%; similar response was not evident in whitefaced breeds. In another experiment involving 873 lambs, intact males, implanted intact males and short scrotum cryptorchids gained faster than ewe and wether lambs. Cryptorchid and wether carcasses had higher carcass grades and dressing percentages than ram lambs.

- (2) In intensive studies on nitrogen metabolism in growing lambs, data indicated that citric acid excretion is 4.3 to 21 times higher in lambs on urea diets than soy protein diets and that dietary nitrogen is more efficiently utilized in urea diets when rations are fed frequently (12 versus 2 times daily).
- (3) Wether lambs (37.9 kg) were fed a basal ration of 50% wheat straw plus corn starch with (1) no supplemental nitrogen; or (2) preformed protein consisting of 3 parts corn gluten meal and 1 part soybean meal; or (3) urea to give 11.5% crude protein equivalent. Five lambs from treatments 2 and 3 were slaughtered after 14 and 60 days and from treatment 1 after 14 days on treatment. Glucose synthesis by liver slices in vitro from U-¹⁴C-serine was increased by treatment 3 vs. 1 and 2 (P<0.05) and with time on treatment. ¹⁴CO₂ production from serine by liver slices was not influenced by diet but was increased with time on treatment. Glucose synthesis and ¹⁴CO₂ production from U-¹⁴C-lactate was not influenced by diet but glucose synthesis was increased with time on treatment (P<0.05). Activities (unit/mg protein/min.) of 3-phosphoglycerate dehydrogenase and D-glycerate dehydrogenase were not influenced by diet or time on treatment. Serine dehydratase was higher in treatment 1 vs. 2 and 3 (P<0.05). The elevated tissue serine concentrations observed with urea feeding cannot be explained by changes in activities of 3 of the enzymes involved in serine synthesis or catabolism. However, urea fed animals had a greater potential for metabolizing serine to glucose than those fed preformed protein.

c. Current Status:

Intensive studies on NPN utilization by growing lambs are continuing. Small numbers (30 to 40) of ram lambs are involved in dietary treatments to assess factors influencing quantities of amino acids and other metabolites absorbed from the gastrointestinal tract. An experiment to evaluate the effect of nutritional environment (energy intake) and sex (intake male vs. female) on the rate, efficiency and composition of growth of over 1,200 Suffolk-sired lambs is nearing completion.

d. Research Plans:

Increased weights of acceptable quality lamb carcasses would have a large, favorable effect on the sheep industry. Thus, major commitments of sheep research resources are planned in the area of developing efficient, heavy lamb production systems. The nutrition component of this program will be

closely coordinated with genetics and breeding, carcass and meats, and management systems to develop the basic information necessary to synchronize nutritional programs with "growth impulse" of edible tissue.

III. REPRODUCTION

A. General Objective. Develop methods for maximizing the number of lambs born and reared per ewe exposed to breeding and the number of lambings per unit of time using genetic, hormonal and nutritional approaches.

B. Specific Programs.

1. Research Area:

Maximize Reproductive Performance in Breeds with High Genetic Capability for Reproductive and Maternal Traits

a. Objectives:

- (1) Identify and intensively evaluate breeds with varying levels of genetic capability for reproduction to assess opportunities for increasing performance through among- and within-breed selection.
- (2) Maximize reproductive performance in sheep with a high genetic capability for reproduction by nutrition and management practices.

b. Research Accomplishments or Progress:

- (1) Ewe lambs (565) representing 19 breed groups were used to evaluate effect of breed, breeding weight, breeding age and growth rate on reproductive performance of lambs bred at 7 to 8 months of age. Breed had a large, significant effect on lambing traits. Rambouillet-cross (R_x) and Finnsheep-cross (F_x) ewes weaned more lambs per ewe exposed and more lambs per ewe lambing than the Suffolk, Hampshire, Rambouillet, Dorset, Targhee, Corriedale and Coarse Wool straightbreds. The F_x ewes produced more lambs born per ewe exposed (134 vs. 75%) and per ewe lambing (161 vs. 102%) than the R_x ewes. A small increase in age of ewe lamb at breeding increased number of ewes lambing and number of lambs born per ewe exposed. Increased ewe age also increased lamb birth weight and lambing difficulty. Condition and body weight of ewe lambs at beginning of breeding and weight at lambing did not affect any of the reproductive traits studied.

- (2) A study involving 825 ewe lambs was conducted to evaluate the influence of breed, heterosis, type of birth and rearing, age of dam, and pre- and postweaning growth rate on components of puberty. Results indicate that, within a breed or breed-cross, preweaning competition among twin and triplet lambs reduces ewe lamb weights at weaning (70 days) and at 160 and 230 days of age and tends to delay puberty until weights characteristic of each breed group are reached. Age of dam influenced lamb preweaning growth importantly, but not age or weight at puberty. Faster preweaning and 70- to 160-day postweaning rate of growth definitely increased percentage of lambs reaching puberty by 8 months of age and, hence, reduced mean age at puberty. Breed and heterosis effects were far more important than the environmental influences of type of birth, type of rearing and age of dam in determining age and weight at puberty. Percentage of lambs reaching puberty by 8 months of age was far higher for F_x ($71 \pm 4\%$) than for R_x ($37 \pm 6\%$) or purebreds ($34 \pm 5\%$) of the Suffolk, Hampshire, Rambouillet, Dorset, Targhee, Corriedale or Coarse Wool breeds. Mean age at puberty was nearly three weeks earlier for F_x (218 days) than for R_x (238 days) or purebreds (245 days) of the seven dam breeds. Limited observations on 3/4 Finn lambs suggest that early sexual maturity in the F_x is due more to heterosis from crossing the Finn with domestic breeds than to early maturity in purebred Finn.
- (3) Four hundred forty-eight, Finn, F_1 ewe lambs six months of age were fed diets containing three levels of protein or energy in a 3x3 factorial design before and during the breeding season. Eighty-eight percent of the ewes produced lambs at a year of age and 55.3, 42.7 and 2.0% of the ewes produced singles, twins and triplets, respectively. Ad libitum feeding of ewe lambs significantly increased ADG and number of lambs born as compared to 87.5 and 75% of ad libitum feeding. An increase of 0.2 lambs per ewe was observed for ad libitum fed ewes. Ewes fed 11% crude protein had greater feed consumption and ADG as compared to ewes fed 13 and 15% crude protein diets, but reproductive traits were similar for the three protein levels.
- (4) To determine the physiological basis for differences in ovulation and lambing rates among breeds of sheep, gonadotropin and steroid hormone levels were measured in 40 lambs representing the Finn, Rambouillet, Hampshire and 1/2 Finn-1/2 Rambouillet breed groups. Preliminary results indicate that ovulation rate at puberty is

higher in the 7/8 or straightbred Finn than in the other breed groups, but that luteinizing hormone levels in the peripheral circulation from 9 to 37 weeks of age is not an accurate predictor of ovulation rate either among or within breed groups.

- (5) Research at the U.S. MARC and other locations has not been able to demonstrate that hormone treatment during the normal breeding season will increase lambs born per ewe exposed to breeding or per ewe lambing.

c. Research Plans:

A comprehensive evaluation of the reproductive performance of additional new breeds, breed-crosses and synthetics will be made on a continuing basis. Efforts will be intensified and expanded to evaluate and maximize reproductive performance of breed groups with a high genetic capability for reproduction under different nutritional regimes and management systems. These areas are highly integrated with the disciplines of nutrition, genetics and breeding, and management systems.

2. Research Area:

Maximize Out-of-Season Breeding of Ewes

a. Objectives:

- (1) Determine the influence of breed on ability of ewes to mate during the anestrus (out-of-season) period.
- (2) Determine the effect of breed on response to exogenous hormones during the anestrus period.
- (3) Obtain the necessary biological understanding required for development of selection criteria or treatment procedures for increasing yearly lambing frequency.
- (4) Determine factors responsible for postpartum anestrus.
- (5) Develop procedures which reduce the interval from parturition to first estrus and pregnancy.
- (6) Evaluation of cleavage and early embryonic losses in ewes induced to breed out-of-season.

b. Research Progress and Current Status:

- (1) Results from a series of experiments involving several hundred ewes of the Rambouillet, Targhee, Hampshire, Dorset, Suffolk, Corriedale, Coarse Wool and Finnsheep-cross (1/2) breeds have documented that out-of-season mating is not feasible in most breeds without some procedure to induce estrus and ovulation. The percentage of ewes lambing without induced mating has ranged from 8 to 25% when exposed to rams in May and 0 to 7% when exposed to rams in June and July.
- (2) Treatment during May and early June of ewes, representing the above breeds, with progestogens and PMS has resulted in 63 to 75% of the ewes lambing. Similar treatment during late June and early July resulted in only 30% of the ewes lambing.
- (3) Influence of season and breed on ovarian and pituitary response was evaluated for Finn and Hampshire ewes treated with progestogen and PMS in May, July and November. Both season and breed independently affect ovulation rate. Ovulation rates for the Finn and Hampshire ewes were 3.4 and 2.2 in May, 2.0 and 1.6 in June and 3.0 and 2.0 in November, respectively. The corresponding ovulation rates for nontreated ewes in November were 2.8 and 1.6. Ovarian follicular response, as determined by plasma estradiol concentration, was not influenced by season or breed. In contrast, the interval from PMS administration to the preovulatory LH surge was shorter in May than July (64.8 vs. 77.1 hr), suggesting a seasonal influence on pituitary responsiveness. Endocrinological differences were not observed between breeds.
- (4) Results indicate that lactation and season interact to diminish the increase in LH secretion which occurs in response to ovariectomy. LH secretion after ovariectomy and the ability to display normal ovarian activity do not correlate as well in ewes as has been observed in other species.
- (5) Fertilization failure was found to be the major contributor to lower fertility in out-of-season mated Finnsheep-cross (3/4) ewes treated with progestogen and PMS. Conception was evaluated by the collection of ova at 48 hr. postmating, embryos at 12 days postmating and lambs at term. Percentage of fertilized ova for out-of-season mated vs. non-treated fall mated ewes was 66.7 and 87.5%,

respectively, while number of accessory sperm/ovum was 4.8 and 79.1, respectively. The percentage of fertilized ova to corpora lutea (CL) at 48 hr. post-mating or embryos to CL at 12 days postmating for the two seasonal groups were 61.5 vs. 80.5% and 51.3 vs. 87.5%, respectively.

- (6) Two hundred fifty ewes were treated with progestogen-PMS and mated in June, 1975. In August, 1975, another 250 ewes were subjected to similar treatment. Single-sire matings (25 ewes per ram) were monitored in each period. Laparotomy was performed on 40% (206) of these ewes, and eggs recovered from oviducts 40 to 60 hr after onset of estrus. Fertilized eggs, as a percentage of total eggs recovered, were 60.6% in June and 61.2% in August. Ewes with one or more fertile eggs, as a percentage of all ewes laparotomized, were 62.8% in June and 69.7% in August. Unsynchronized control ewes subjected to laparotomy in November, 1975, yielded 91.4% fertilized eggs and 95.2% ewes with one or more fertile eggs. Sperm numbers in oviduct fluids at egg recovery were approximately 100-fold higher and accessory sperm on eggs were 10-fold higher for control ewes than for synchronized ewes. These reduced sperm numbers in treated ewes indicate that sperm transport is impaired by the synchronization treatment. Lambing data for ewes not subjected to surgery will be available in early 1976.

d. Research Plans:

Studies initiated in 1974-75 should yield within 2 to 3 years the necessary information to determine the feasibility of developing treatment regimes for induced out-of-season mating. If the results of these studies indicate development of an appropriate regimen has a high probability of success, efforts in this area will continue. These efforts are and will continue to be highly integrated with evaluating ram effects on out-of-season breeding.

3. Research Area:

Out-of-Season Breeding of Rams

a. Objectives:

- (1) Determine seasonal variation in libido and sperm quality and quantity of rams.
- (2) Determine the proportion of variation in response of out-of-season breeding treatment regimes that is associated with differences among rams.

- (3) Evaluate breed differences in ability of rams to function during out-of-season breeding.
- (4) Develop procedures to increase libido and control spermatogenesis during out-of-season breeding.

b. Research Accomplishments or Progress:

- (1) In a study involving 204 Targhee ewes and 15 rams allotted at the rate of 8, 12, 16 or 20 synchronized ewes per ram, ram to ewe ratio had no influence on percentage of ewes mated, conception rate at the synchronized estrus, percentage of ewes lambing, number of lambs born per ewe lambing or average lambing date. Seventy-six percent of the ewes were marked by rams within 8 days after progestogen treatment and overall conception rate was 84.5%. The study demonstrated that one ram per 20 ewes is sufficient for maximum mating activity and conception rate in ewes mated at a synchronized estrus.
- (2) Efforts directed toward evaluating the ram's influence on variation in success of out-of-season breeding were initiated September, 1974. The initial experiment involved a comprehensive evaluation of seasonal changes in libido, semen characteristics and circulating levels of androgens of Finn and Suffolk rams from September, 1974, to September, 1975. A procedure was developed for assessing sexual activity (libido) of individual rams. Mating activity measured by this procedure and serum levels of LH and testosterone in Finnish Landrace and Suffolk rams were determined at eight-week intervals from October, 1974, to October, 1975. Seasonal changes were observed for serum LH, testosterone and libido index scores. Mating activity in rams was highest for both breeds during the peak breeding season (October), and declined 50% by late spring and summer before increasing the following October.

Serum LH concentrations were lowest in May (.54 ng/ml) and increased abruptly in July (>2 ng/ml) when daily photoperiod began to decrease. Serum testosterone concentrations (>6 ng/ml) and mating activity were highest during the October evaluations. Testosterone decreased gradually through the winter months reaching lowest levels in late March (2.06 ng/ml in Finn rams and 1.01 ng/ml in Suffolk rams). Thereafter, concentrations increased again in preparation for fall breeding. A positive correlation ($r = .59$) existed between mean testosterone and mating scores collected

across months suggesting that seasonal fluctuations in serum testosterone influences the sexual behavior of rams. A temporal relationship was not detected between circulating testosterone and sexual behavior.

- (3) The existence of secretory surges of both LH (luteinizing hormone) and T (testosterone) in the ram have been documented. However, no consistent relationship has been shown to exist between elevations in plasma LH and resultant T peaks. This study was designed to better define the proposed LH:T interrelationships and assess the effects with regard to season. In early September, adult Suffolk-Hampshire rams were penned individually and a jugular cannula inserted for subsequent bleeding. Following 24 hours of adaptation, 48 samples were taken from each ram at 30 minute intervals. In a like manner, these same rams were sampled in early May. Plasma was prepared and kept frozen until future analysis. Radioimmunoassay for both LH and T was performed on all samples.

Since T levels increased when LH was greater than 2 ng/ml, LH values greater than 2 ng/ml were designated as peaks while those less were considered baseline levels. Both mean and baseline levels of LH were higher during the normal breeding period with LH surges being more frequent; however, magnitude of the LH peaks was no different during the months studied (6.33 vs. 6.50 ng/ml). A wide range of T (0.5 - 16.0 ng/ml) existed within individual rams with mean T levels nearly 50% higher in September than in May. A temporal relationship between LH release and T secretion seems quite conclusive since obvious surges in LH were followed by dramatic increases in plasma T. The elapsed time between peaks of LH and T was either 30 or 60 minutes in these studies.

- (4) Studies were conducted to evaluate endocrine function in short scrotum and cryptorchid rams (CR). When testosterone (T) was measured in short scrotum rams (a semi-cryptorchid condition), values were no different from intact controls (IR); however, radioimmunoassayable LH was elevated more than two-fold. To understand the relationships between LH and T, 20 prepuberal rams were made surgically cryptorchid and patterns of LH and T studied at 6 months of age. Five of these animals and 5 IR were bled at 30 min intervals for 6 hr to detect episodic release of LH.

Both CR and IR showed episodic patterns of LH and T. Although average T values were not different (CR 9.1 ± 1.2 and IR 7.8 ± 1.2 ng/ml), LH was significantly increased by treatment (CR 7.8 ± 1.0 and IR 1.0 ± 0.1 ng/ml). Since these differences in LH concentrations are apparently not the result of differences in T, physiological doses of T (25 mg), dihydrotestosterone (DHT, 25 mg) and 17β -estradiol (E_2 , 100 μ g) were each given to 5 cryptorchid rams. When LH values at 6 hr post-injection were compared with pre-injection levels, intramuscular T and DHT had no effect while E_2 decreased serum LH from 7.0 ± 0.9 to 1.4 ± 0.4 ng/ml. These data indicate that E_2 may control or modulate secretion of LH in the ram.

c. Current Status and Research Plans:

Efforts will be directed toward satisfying the above objectives and will be highly integrated with projects in the female directed toward out-of-season breeding.

IV. CARCASS AND MEATS

A. General Objective. Develop procedures to optimize carcass composition, palatability and product utility and acceptability with special emphasis on heavy slaughter weight lambs.

B. Specific Programs.

1. Research Area:

Heavy Lamb Production

a. Objectives:

- (1) Develop the understanding of tissue growth and deposition necessary to favorably modify these maturing patterns.
- (2) Develop efficient systems of producing heavy lambs with optimum lean-to-fat ratio and acceptable palatability.

b. Research Accomplishments or Progress:

One hundred twenty black faced rams were fed a high energy (3.2 Mcal M.E./kg), high protein (16.8%) protein beginning at mean age of 95 days and assigned to one of three slaughter groups, having mean ages of 26, 34 and 42 weeks. Means (unadjusted) of hot carcass weight at these slaughter points were 29.3, 39.0 and 43.1 kg, respectively. Warner-Bratzler

shear values and taste panel juiciness scores did not vary significantly over the three slaughter groups. Determination of tenderness by taste panel, however, indicated that two oldest groups of rams were less tender than the youngest group. Flavor and fat aroma were objectionable in the two heavier groups of rams. Further interpretation of these data is currently under way.

c. Current Status:

A fully integrated, multidiscipline research effort is being initiated. Currently active experiments include efforts to determine the effect of energy intake, sex, age and weight on carcass composition and palatability of Suffolk-sired lambs. Evaluation of the effect of these and other production variables on carcass composition and palatability will be quantified.

d. Research Plans:

The production of heavy lamb carcasses of desired quality and composition will require the lean growth potential of the best available germ plasm under favorable, nutritional regimes and exogenous growth stimuli. Increased knowledge of muscle biology will form an integral part of the understanding necessary to accomplish this objective.

2. Research Area:

Lamb Carcass Composition and Palatability

a. Objectives:

- (1) Develop procedures to more accurately determine composition of both the live animal and of the carcass.
- (2) Develop information necessary to improve grading of carcass quality and yield.

b. Research Accomplishments or Progress:

One experiment designed to evaluate the effects of carcass weight on carcass composition and grading criteria has been completed. One hundred forty-one lambs from Hampshire (H), Dorset (D) and Rambouillet (R) ewes sired by H, D, R and Finnsheep rams were slaughtered after 22, 26 and 33 weeks on feed. The 6th through 12th rib was physically separated into fat, lean and bone, and chemical analysis of the longissimus muscle determined. The mean carcass quality grade was not affected by carcass weight. Linear increases in rib feathering, flank fat streaking, flank firmness and marbling as

carcass weight increased were offset by increases in discounts for "buckiness". Linear increases in fat thickness, percentage of kidney and pelvic fat resulted in decreased percentages of lean and bone at heavier carcass weights.

c. Current Status:

In collaboration with Wilson and Co., retail cut yields, composition and meat quality information was obtained on 800 ewe and wether lambs as part of the Germ Plasm Evaluation Project. These data will also be utilized to determine factors influencing product yield and desirability.

d. Research Plans:

It is anticipated that requirements and objectives in this research area will be developed further in coordination with the Agricultural Marketing Service. Definitive experiments within this framework will be undertaken to identify those variables most responsible for detecting differences in amount of edible product and in organoleptic characteristics among lamb carcasses. The heavy lamb production systems project described in 1. above, offers the opportunity to evaluate existing live animal and carcass predictors of yield and quality and to assess the merit of newly developed predictors.

V. LIVESTOCK ENGINEERING

A. General Objective. Develop, evaluate and demonstrate facility design, equipment and procedures to reduce the per unit labor requirement in sheep production, provide for efficient animal performance and reduce losses from predators.

B. Specific Programs.

1. Research Area:

Facilities and Equipment

a. Objective:

- (1) Develop automated facilities, mechanized equipment and labor-efficient techniques for lambing, health program maintenance, feeding, shearing and waste removal.

b. Research Accomplishments or Progress:

- (1) An automated lamb nurser used in rearing orphan or early weaned lambs was developed in 1970 and has been successfully used since that time.

- (2) A spray-shower dip has recently been completed. The design was modified and improved from those used in New Zealand.
- (3) Equipment has been installed to measure the quantity and quality of runoff from the intensive sheep facilities area. This area holds up to about 2,500 ewes and 2,500 feeder lambs.

c. Research Plans:

Success of the sheep industry is closely tied to the development of labor-efficient production systems. For this reason, major research efforts are planned in this area. These will become more fully activated as the agricultural engineering component of the U.S. MARC Program develops.

2. Research Area:

Shelter

a. Objectives:

- (1) Develop and evaluate methods of sheltering which provide for maximum lamb viability, rapid and efficient lamb growth and maximum reproductive performance of ewes.
- (2) Determine principles underlying optimum types of housing, housing density and the use of shades and windbreaks.

b. Research Plans:

Intensive sheep production systems utilizing accelerated lambing programs require adequate and efficient housing. Such facilities including an all-weather lambing facility are being developed at the U.S. MARC.

3. Research Area:

Predator Control

a. Objectives:

- (1) Document the extent of predator losses in U.S. MARC populations.
- (2) Develop effective guarding techniques, fencing methods, repellents, trapping techniques or warning devices to reduce or eliminate economic losses from coyote and dog predation.

b. Current Status:

Verified predator losses, by year, were 1.0, .2, 2.2, .7, 1.3, .1, 3.4, .6 and .2% of June sheep inventory from 1967 to 1975.

c. Research Plans:

At this time, it is anticipated that major predator control research will be initiated in 1977. The primary focus of this research is expected to be on the use of guard dogs. Facilities will also permit the evaluation of the economic feasibility and effectiveness of other promising control methods.

VI. FLOCK HEALTH AND DISEASE MANAGEMENT

A. General Objective. Develop procedures for general flock health maintenance including practical solutions to reduce economic loss from specific sheep health problems; such as, pneumonia, polyarthriti-s, listeriosis, ketosis, mastitis, enterotoxemia and internal parasites.

B. Specific Programs.

1. Research Area:

Develop effective prophylactic therapies to prevent the occurrence of pneumonia and polyarthriti-s and reduce losses from foot diseases and internal parasites in intensively managed sheep flocks.

a. Objectives:

- (1) Develop rapid practical diagnostic procedures to identify carrier animals that are a possible source of viral, chlamydial, mycoplasmal and bacterial agents involved in ovine pneumonia.
- (2) Devise management practices to eliminate carrier animals that are identified as sources of infectious agents involved in ovine pneumonia.
- (3) Evaluate methods of stimulation of the immune system of the prenatal and neonatal lamb.
- (4) Evaluate economic losses that occur from infestation of intensively managed sheep flocks with internal parasites.
- (5) Develop management practices and treatment procedures to overcome economic losses attributable to internal parasites.

2. Research Area:

Determine the role of nutrition, facilities and husbandry practices in the prevention and recovery from diseases. Specific efforts will include the prevention of listeriosis, ketosis and enterotoxemia through utilization of nutritional and management procedures.

a. Objectives:

- (1) Determine the effect of various levels of energy, protein, vitamin and mineral intake on the immune system of growing, gestating and lactating ovine populations.
- (2) Evaluate the role silage feeding plays in the incidence of listeriosis. Develop silage treatment and management practices to eliminate the source of infection.
- (3) Develop specific nutritional regimes that will return the convalescing enteric and/or respiratory infected ovine to an economical production status.

3. Research Area:

Develop management procedures, hormonal therapy and/or medical treatments to prevent the occurrence of mastitis in ewes whose lambs are weaned as early as one day of age.

a. Objectives:

- (1) Identify the various microbiological agents present when mastitis occurs and determine the specific role each agent plays in the cause of mammary gland inflammation.
- (2) Determine the effectiveness of various hormone treatments and nutritional practices on depression of milk production as a method of controlling mastitis. An important part of this project would be to ascertain the effect of treatments on future milk production and reproductive performance.

C. Current Status and Research Plans.

The U.S. MARC Veterinary Medical Officer is implementing effective technology now available to improve and maintain flock health. Research programs will be initiated pending establishment of a Herd Health and Disease Management Research Unit. Collaborative efforts with the National Animal Disease Center and other appropriate laboratories will be essential if these research efforts are to be effective.

VII. MANAGEMENT SYSTEMS

A. General Objectives. Develop production strategies which optimally integrate economics and technology to maximize production resource conversion rate. Identify technological voids for the purpose of more accurate assessment of research priorities.

B. Specific Programs.

1. Research Area:

Model Simulation

a. Objectives:

- (1) Construct and validate biological input/output models of sheep production systems.
- (2) Evaluate economic efficiency of alternative sheep production systems.
- (3) Identify and assess relative priority of information deficiencies.

b. Current Status:

Initial projections of flock dynamics, nutritional regimes, facility and labor requirements and production levels have been completed for flocks under annual and accelerated lambing programs. Experimental validation of projected resource requirements and product yields has been initiated. A cooperative agreement with the Texas Agricultural Experiment Station has made available beef cattle simulation models which will be modified at an early date to supplement efforts in this area.

c. Research Plans:

Systems analysis utilizing simulation modeling is planned as the focal area of sheep management systems research and as a major component of the total U.S. MARC Sheep Research Program. Development of component models of flock dynamics, nutritional requirements, feed production and product yield will closely parallel similar efforts in beef cattle since many model segments will be interchangeable with only slight modifications.

2. Research Area:

Alternative Sheep Production Systems

a. Objectives:

- (1) Experimentally evaluate economic efficiency of alternative production systems.
- (2) Determine feasibility and problems of implementing new technology on a production scale.

b. Current Status:

A project is being initiated to evaluate requirements for, and output from, production systems which represent different levels of management intensiveness.

- (1) Highest level of intensiveness: Accelerated lambing of ewe germ plasm that has a high reproduction rate and receptivity to hormone therapy and/or a minimum anaestrous to permit out-of-season breeding. High level of confinement and labor, facilities, nutrition, early weaning, etc., necessary to reach objective of 210-225% lamb crop weaned per year. Use of labor and facilities at level necessary to save a high percentage (90%) of lambs dropped. Maximum output per breeding unit is a primary objective of this system, which is expected to identify technological voids and implementation problems for highly intensive sheep production systems.
- (2) Intermediate level of intensiveness: Management practices to be similar to (1) above, except that only spring lambing will be practiced and level of confinement will be considerably less. Labor, facilities, early weaning, nutrition, etc., will be used at the level necessary to save a high percentage (90%) of the lambs dropped. The objective is for 175-180% lamb crop weaned per year.
- (3) Lowest level of intensiveness: This system will utilize outside lambing with minimal facility and labor requirement. Germ plasm with high reproductive rate similar to (1) and (2) above, will be used. Labor necessary to keep lamb death losses below 15-20 percent will be employed. No early weaning (one day) will be practiced. The objective is for 140-150% lamb crop weaned per year.

Ewes of 1/2 Finn breeding will be bred to Suffolk rams in all three systems. Lambs will not be individually identified and only limited biological data will be collected. Inputs (facilities, labor, feed, etc.) and outputs (lamb, wool and cull ewes) will be accurately determined as a basis for evaluating each production system. Flocks of 500+ ewes planned for each system will be reached within a year. The flocks currently include from 200 to 400 ewes each.

c. Research Plans:

Sheep production system evaluation is indicated in order to demonstrate the implementation of new technology on a primary-enterprise basis and to validate biological simulation models to be utilized in both sheep and beef cattle management systems research. The nature of future projects in this area will be determined by the results of the current level-of-intensiveness project and the modeling efforts described in 1. above.

3. Research Area:

Labor Requirements

a. Objectives:

- (1) Determine labor requirements of currently used management practices.
- (2) Develop procedures for increasing labor efficiency of sheep production.

b. Current Status:

The measurement of the labor required for different husbandry operations in the level-of-intensiveness project described in 2. above, and other ongoing research projects is planned.

c. Research Plans:

Major efforts in the development of efficient labor utilization procedures will be in close cooperation with the Agricultural Engineering Research Unit. The assessment of labor requirements of production systems will constitute an essential part of an economic evaluation of these systems.

U.S. MEAT ANIMAL RESEARCH CENTER

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